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(54) **SYSTEM AND METHOD FOR SELECTION OF A REFERENCE DIE**

(75) Inventors: **Clyde Maxwell Guest; Rajiv Roy**, both of Plano; **Charles Kenneth Harris**, Dallas, all of TX (US)

(73) Assignee: **Semiconductor Technologies & Instruments, Inc.**, Plano, TX (US)

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(58) **Field of Search** 382/145, 148, 382/149, 144, 168, 170, 146, 147, 150, 151, 152; 356/237.5, 237.4, 601, 613, 390; 438/16; 348/87, 126; 250/559.2, 559.39, 559.46; 700/110; 702/40, 159

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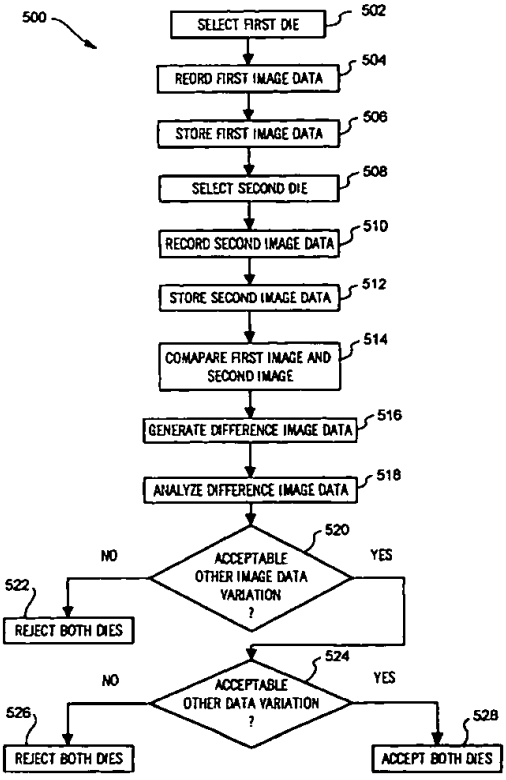
Primary Examiner—Leo Boudreau
Assistant Examiner—Brian P. Werner
(74) *Attorney, Agent, or Firm*—Christopher J. Rourk; Akin, Gump, Strauss, Hauer & Feld, L.L.P.

(57) **ABSTRACT**

A system for selecting reference die images, such as for use with a visual die inspection system, is provided. The system includes a die image comparator, which compares a first die image to a second die image in order to create a difference image that contains only the differences between the two die images. The system also includes a difference image analysis system that receives data from the die image comparator. The difference image analysis system analyzes the difference image and determines whether there are any features of the difference image that indicate that either the first die image or the second die image should not be used as a reference die image.

26 Claims, 8 Drawing Sheets



Double Patenting

visual inspection of dies formed from the wafer. Method **600** may be used in a system such as the difference analyzer **210** or in other suitable systems of visual inspection systems.

Method **600** uses predetermined analytically or empirically developed criteria for accepting or rejecting die images so as to select reference die images for subsequent visual inspection of other dies that have been formed from the silicon wafer. Accordingly, the sensitivity for allowable defects for such dies is typically set to a much higher threshold than the allowable sensitivity for defects for variations between the reference die image and individual dies tested on the wafer. Thus, even though differences between two dies may result in the die images being rejected for the purpose of use as a reference die, each die may subsequently be determined to be acceptable for use in production.

FIG. **7** is a flowchart of a method **700** for analyzing other image data in accordance with an exemplary embodiment of the present invention. Method **700** may be used in conjunction with the difference analyzer **210** of FIG. **2** or with other suitable systems, and uses image data other than brightness that may be used to perform inspection of dies. For example, infrared light, ultraviolet light, or light of predetermined color may be used to detect defects or flaws that may not be detected as well by simple brightness variations.

Method **700** begins at step **702**, where image data from a difference image is sorted. The method then proceeds to step **704**, where the image data frequency is tabulated. For example, a frequency histogram of image data magnitude may be created at step **704**. The method then proceeds to step **706**, where it is determined whether there is a slope change from negative to positive over the tabulated image data frequency data. If no slope change from negative to positive occurs, the method proceeds to step **708** and both dies are accepted for use as reference dies. Otherwise, the method proceeds to step **710**.

At step **710**, the length of any image data excursion that resulted in an increase in slope is determined. For example, the image data excursion may extend over a range of image data values. In an eight-bit system, for example, the image data values would range from 0 to 255. In accordance with the exemplary method **700**, the length along the axis of the image data excursion is determined at step **710**. The method then proceeds to step **712** where it is determined whether the length is acceptable. For example, it may be analytically or empirically determined that an excursion for the image data being used that has a length that exceeds a predetermined number of points on the image data scale will result in devices that misoperate with an unacceptable frequency. If it is determined at step **712** that the length is unacceptable, the method proceeds to step **714** and both dies are rejected for use as reference images. If it is determined that the length of the image data excursion is acceptable at step **712**, the method proceeds to step **716**.

At step **716**, the defect dimensions from the pixel coordinates of the pixels that define the image data excursion are determined. For example, a defect may be a line, a circle, a square, an irregular shape, or another shape. The shape of such defects is determined at step **716**, and the method proceeds to step **718**. At step **718** it is determined whether the dimensions of the defect are acceptable. For example, it may be analytically or empirically determined that defects having a length and width that exceed a certain predetermined value, such as five microns, produce devices that have an unacceptable failure probability. If the dimensions are determined to be unacceptable at step **718**, the method proceeds to step **720** and both die images are rejected for use as reference images. Otherwise, the method proceeds to step **722**.

At step **722**, the defect density is determined from the defect coordinates. For example, it may be analytically or empirically determined that a predetermined number of smaller defects within a larger area will result in a device that has an unacceptable failure probability. After the defect density is determined at step **722**, the method proceeds to step **724** where it is determined whether the density of defects is acceptable. If the density of defects is not acceptable, the method proceeds to step **726** and both dies are rejected for use as reference images. Otherwise, the method proceeds to step **728** and both dies are accepted for use as reference images.

In operation, method **700** is used to analyze difference image data created by comparing a first die image and a second die image. The difference image is analyzed to determine whether to accept or reject both the first die and second die as potential reference images for subsequent visual inspection of dies formed from the wafer. Method **700** may be used in a system such as the difference analyzer **210** or in other suitable systems of visual inspection systems.

Method **700** uses predetermined analytically or empirically developed criteria for accepting or rejecting die images so as to select reference die images for subsequent visual inspection of other dies that have been formed from the silicon wafer. Accordingly, the sensitivity for allowable defects for such dies is typically set to a much higher threshold than the allowable sensitivity for defects for variations between the reference die image and individual dies tested on the wafer. Thus, even though differences between two dies may result in the die images being rejected for the purpose of use as a reference die, each die may subsequently be determined to be acceptable for use in production.

Although preferred and exemplary embodiments of reference die selection systems and methods for selecting reference dies have been described in detail herein, those skilled in the art will also recognize that various substitutions and modifications may be made to the systems and methods without departing from the scope and spirit of the appended claims.

What is claimed is:

1. A system for selection of a reference die image comprising:

a die image comparator operable to create a difference image based upon a first die image and a second die image; and

a difference image analysis system coupled to the die image comparator, the difference image analysis system generating histogram data from the difference image and analyzing the slope of the histogram data to determine the length of a region over which the slope of the histogram data increases and then decreases, wherein the length of the anomalous region is then used to determine whether the first die image and the second die image may each be used as the reference die image for subsequent comparison with other dies on a wafer.

2. The system of claim 1 further comprising a die imaging system coupled to the die image comparator, the die imaging system operable to create a digital representation of a die.

3. The system of claim 1 further comprising a die image storage system coupled to the die image comparator, the die image storage system operable to store data representative of the first die image and the second die image.

4. The system of claim 1 wherein the difference image analysis system further comprises a slope detector, the slope detector operable to determine whether the slope of a histogram changes from negative to positive.

5. The system of claim 1 wherein the difference image analysis system further comprises a size detector, the size detector operable to determine whether a size of the anomalous region exceeds a predetermined allowable size.

6. The system of claim 1 wherein the difference image analysis system further comprises a density detector, the density detector operable to determine whether a number of anomalous regions per unit area exceeds a predetermined allowable number of anomalous regions per unit area.

7. A system for inspecting dies comprising:

a camera configured to obtain an image of two or more dies; and

a reference die detection system coupled to the camera, the reference die detection system operable to analyze slope changes in histogram data a difference between a first die image and a second die image to determine the length of a region over which the slope of the histogram data increases and then decreases, wherein the length of the anomalous region is then used to determine whether the first die image and the second die image can be used as reference images for subsequent comparison with other dies on a wafer.

8. The system of claim 7 wherein the reference die detection system further comprises an image comparator operable to produce a difference image from the first die image and the second die image.

9. The system of claim 8 wherein the reference die detection system further comprises a difference analyzer coupled to the image comparator, the difference analyzer operable to determine whether the difference image contains unacceptable features.

10. The system of claim 9 wherein the difference analyzer further comprises a data sorter that is operable to receive brightness data associated with a plurality of pixels of the difference image and to create a histogram from the brightness data.

11. The system of claim 10 wherein the difference analyzer further comprises a slope detector coupled to the data sorter, the slope detector operable to determine whether a slope of the brightness data histogram changes from negative to positive as a brightness magnitude increases.

12. The system of claim 10 wherein the difference analyzer further comprises a dimension analyzer that is operable to determine (a) one or more dimensions for a group of pixels, where each pixel has a brightness magnitude that exceeds a predetermined allowable magnitude, and (b) whether one or more dimensions of the group of pixels exceeds one or more predetermined allowable dimensions.

13. The system of claim 10 wherein the difference analyzer further comprises a density analyzer that is operable to determine (a) one or more dimensions of two or more groups of pixels, where each group of pixels has a brightness magnitude that exceeds a predetermined allowable magnitude, and (b) whether a density of the two or more groups of pixels per unit area exceeds a predetermined allowable density.

14. The system of claim 9 wherein the difference analyzer further comprises a data sorter that is operable to receive image data associated with a plurality of pixels of the difference image and to create a histogram from the image data.

15. The system of claim 14 wherein the difference analyzer further comprises a slope detector coupled to the data sorter, the slope detector operable to determine whether a slope of the image data histogram changes from negative to positive as an image data magnitude increases.

16. The system of claim 14 wherein the difference analyzer further comprises a dimension analyzer that is operable to determine (a) one or more dimensions of a group of pixels, where each group of pixels has an image data magnitude that exceeds a predetermined allowable magnitude, and (b) whether the dimensions of the group of pixels per unit area exceeds one or more predetermined allowable dimensions.

17. The system of claim 14 wherein the difference analyzer further comprises a density analyzer that is operable to determine (a) one or more dimensions of two or more groups of pixels, where each group of pixels has an image data magnitude that exceeds a predetermined allowable magnitude, and (b) whether a density of the two or more groups of pixels per unit area exceeds a predetermined allowable density.

18. A method for selecting a reference die image comprising:

subtracting a first die image from a second die image to create a difference image;

generating histogram data from the difference image;

determining the length of a region over which a slope of the histogram data increases and then decreases;

determining whether the difference image contains unacceptable data based on whether the length of the region exceeds predetermined allowable criteria; and determining whether the first die image and the second die image can be used as reference images for subsequent comparison with other dies on the wafer.

19. The method of claim 18 wherein subtracting the first die image from the second die image comprises subtracting brightness data for each pixel of the first die image from brightness data for a corresponding pixel of the second die image.

20. The method of claim 18 wherein subtracting the first die image from the second die image comprises subtracting image data other than brightness data for each pixel of the first die image from image data other than brightness data for a corresponding pixel of the second die image.

21. The method of claim 18 wherein determining whether the difference image contains unacceptable data comprises:

forming a histogram from difference image data; and

determining whether a slope of the histogram changes from negative to positive.

22. The method of claim 18 wherein determining whether the difference image contains unacceptable data comprises determining whether a size of an area having a brightness deviation exceeds a predetermined allowable size.

23. The method of claim 18 wherein determining whether the difference image contains unacceptable data comprises determining whether a size of an area having an image data deviation for image data other than brightness data that exceeds a predetermined allowable size.

24. The method of claim 18 wherein determining whether the difference image contains unacceptable data comprises determining whether a number of areas having brightness deviations exceeds a predetermined allowable number of areas having brightness deviations per unit area.

25. The method of claim 18 wherein determining whether the difference image contains unacceptable data comprises determining whether a number of areas having other image data deviations exceeds a predetermined allowable number of areas having image data deviations per unit area for image data other than brightness data.

26. The method of claim 18 further comprising:

selecting two or more difference images that do not contain unacceptable data, where each difference image is selected from a different predetermined region of the silicon wafer; and

combining the die images used to create the two or more difference images to form a reference image for use in comparing with each die of the silicon wafer.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,252,981 B1
DATED : June 26, 2001
INVENTOR(S) : Guest et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 13,
Line 19, before "a difference between", insert -- derived from --.

Signed and Sealed this

Twenty-fifth Day of December, 2001

Attest:

Attesting Officer

JAMES E. ROGAN
Director of the United States Patent and Trademark Office